

## **Specsim: The MIRI Medium Resolution Spectrometer Simulator**

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**Abstract.** MIRI, the Mid-InfraRed Instrument, is one of four instruments being built for the James Webb Space Telescope. It is being developed jointly between an European Consortium (21 institutes from 10 countries, under the auspices of ESA), and the US. MIRI consists of an imager, a coronagraph, a low-resolution spectrograph, and an Integral Field Unit (IFU) Medium Resolution Spectrometer (MIRI-MRS). The latter will be the first mid-infrared IFU spectrograph, and one of the first IFUs to be used in a space mission. To give the MIRI community a preview of the properties of the MIRI-MRS data products before the telescope is operational, the Specsim tool has been developed to model, in software, the operation of the spectrometer. Specsim generates synthetic data frames approximating those which will be taken by the instrument in orbit. The program models astronomical sources and transforms them into detector frames using the predicted optical properties of the telescope and MIRI. These frames can then be used to illustrate and inform a range of operational activities, including data calibration strategies and the development and testing of the data reduction software for the MIRI-MRS. Specsim will serve as a means of communication between the many consortium members by providing a way to easily illustrate the performance of the spectrometer under different circumstances, tolerances of components and design scenarios.

### **1. The MIRI Medium Resolution Spectrometer**

The MIRI-MRS is an integral field unit (IFU) spectrometer (Wright et al. 2004), which allows spectroscopy to be carried out on a 2-dimensional area of sky in a single observation. The primary component of the IFU is its image-slicing mirror, which divides the rectangular field of view into a number of narrow slices. These are then arranged along the entrance slit of a first-order diffraction grating, which carries out the dispersion.

The spectrometer operates over the range 5–28  $\mu\text{m}$ , with a resolution of  $R \sim 3000$ . The spectral band is divided into 4 IFU channels, which are observed

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simultaneously. Each channel is equipped with an IFU image slicer designed to match the width of each slice to the diffraction-limited point-spread function of the telescope, at the wavelength of each channel.

An observation over the entire spectral band is carried out in a set of three exposures, the spectral band of each IFU channel being subdivided into 3 sub-bands by means of dichroic filters. The data from each exposure are captured on one of two  $1024 \times 1024$  pixel detectors (one for each pair of image slicer channels: (1A & 2A), (3A & 4A), (1B & 2B) *etc.* The expected sensitivity of the instrument is  $1.210^{-20} \text{ Wm}^{-2}$  at  $6.4 \mu\text{m}$ , and  $5.610^{-20} \text{ Wm}^{-2}$  at  $22.5 \mu\text{m}$ , and its field of view widens with increasing channel number. The main functional parameters for the MIRI-MRS are summarised in Table 1.

Table 1. Summary of the MIRI-MRS parameters

Channel	FoV (arcsec <sup>2</sup> )	Slices	$\lambda$ ( $\mu\text{m}$ )	R <sub>spectral</sub>	Exposure
1	3.70×3.70	21	4.87 – 5.82	2450 – 3710	A
			5.62 – 6.73	2450 – 3710	B
			6.49 – 7.76	2450 – 3710	C
2	4.70×4.51	17	7.45 – 8.90	2480 – 3690	A
			8.61 – 10.28	2480 – 3690	B
			9.94 – 11.87	2480 – 3690	C
3	6.20×6.13	16	11.47 – 13.67	2510 – 3730	A
			13.25 – 15.80	2510 – 3730	B
			15.30 – 18.24	2510 – 3730	C
4	7.74×7.93	12	17.54 – 21.10	2070 – 2490	A
			20.44 – 24.72	2070 – 2490	B
			23.84 – 28.82	2070 – 2490	C

The science goals of the MIRI-MRS encompass a broad area of study, including the formation and evolution of galaxies, the life-cycle of stars and stellar systems, the study of molecular clouds as the focus for star and planet formation, and investigation of planetary evolution conducive to life (Gardener et al. 2005).

## 2. Specsim: Modelling the Sky

Specsim, an application developed in IDL, generates FITS frames which approximate the images which will be produced by the MIRI-MRS.

The program allows the user to build a model of the instrument’s field of view, using a set of primitives to specify the morphological and spectral characteristics of each astronomical target in the field. These currently include point and extended sources, black-body and polynomial continuum profiles, broad and narrow spectral lines and some commonly observed spectral elements such as the

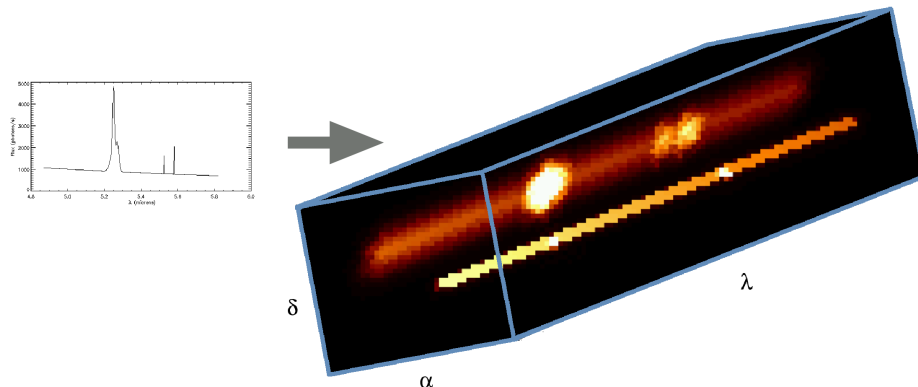


Figure 1. Specsim target simulation cube (right), showing a point-source in continuum with two narrow lines, and an extended source with a broad line and two narrow spectral lines. The plot (left) shows the spectrum of the extended source, generated by combining several of Specsim’s target primitives. In particular, the complex line at  $5.25\mu\text{m}$  was constructed using three broad-line components. The two narrow lines were modelled with a simple narrow line function, and the continuum using the black-body target primitive.

9.7 and  $18\mu\text{m}$  silicate features. The target primitives provided may be used in combination to construct model astronomical fields of arbitrary complexity.

The user-specified target model, together with Specsim’s internal models of the zodiacal background, contributions from the telescope’s solar shield, *etc.*, are used to generate a target simulation cube, representing the instrument’s field of view over each channel’s spectral range (Figure 1).

### 3. Specsim: Modelling the MIRI-MRS

Once a model of the target field of view has been produced, Specsim simulates the function of the spectrograph, producing a simulated spectroscopic observation of the field.

This is carried out by first applying any contribution to the observed flux by the instrument’s optics and electronics to the sky model. Data files defining these may be provided by the user, allowing the effect of instrument characteristics (detector QE, optical efficiency, *etc.*) on the final spectrometer image to be studied. The next step in the process is to simulate the image slicer, by assigning each pixel in the sky model to an IFU slice, depending on its location in the field of view. Geometric deformations can then be applied, simulating the optical path of the telescope, the spectrometer’s pre-optics and the image-slicing mirror. Dispersion of the image slices is then carried out, mapping these onto one half of the detector image, according to IFU channel. Finally, cosmic rays, photon and read-noise are added and on-sky integration is implemented (Figure 2).

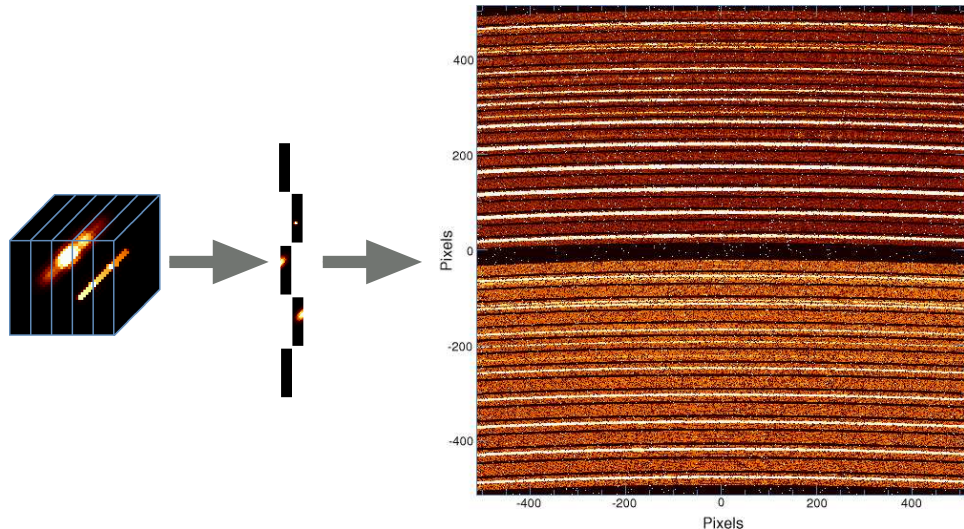


Figure 2. Speccsim segments the target cube to simulate the IFU image slicer (left), the slices are aligned as for input into the diffraction grating (centre), and finally they are dispersed. The simulated spectra for each pair of channels are mapped onto each of two  $1024 \times 1024$  detectors (right).

Both the sky model cube and the detector image are provided as output for the user. This allows the detector frames to be processed, analysed and compared with the input targets, thus providing an useful test for the development of the MIRI data reduction software, testing calibration strategies and observation planning.

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